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Beyond Sustainable Intensification: Transitioning Primary Sectors through Reconfiguring Land-Use

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Abstract: Internationally there is a desire to transition farming systems towards more sustainable production in response to global and local social and environmental challenges. This transition has often been linked with a movement towards 'sustainable intensification' which, although having advantages, has raised questions about a lack of attention to, for example, social and ethical consideration of food and fibre production. Whilst there is general consensus that a transition is required, what is much less clear is what transitioned agricultural sectors would look like in terms of land-use configurations and how such a change can be achieved. Using New Zealand as an example, this paper provides some initial views on what such a reconfiguration may entail. The paper identifies and assesses a range of possible alternative land use configurations that, in general, lead to landscape/regional diversification. The importance of incorporating new high value low intensity (niche) systems into the landscape is highlighted. Development of these niches to achieve scale is shown to be key to the transition process. The joint role of the private (through markets) and public (through policy) sectors in driving the transition is highlighted.

Keywords: mixed-use; diversification; farming systems; land use policy; bioeconomy; New Zealand

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1. Introduction and Background

Internationally, transitioning farming methods away from increased productivity towards sustainable production is increasingly desirable [1–5]. However, this transition generally involves movement towards 'sustainable intensification' which whilst having some advantages (including increased yields and food productivity per area [6]) has recognized drawbacks including a lack of attention to social and ethical aspects of food and fibre production and security [7–12].

Despite international rhetoric towards a more sustainable agricultural model, Ingram notes that "the agricultural sector as a whole has made limited progress on sustainability transitions pathways" [2] (p. 118). A significant issue, recognised by a number of scholars, is that established regimes are "locked in" to existing practices and systems networks, with little ability for niches to impact and alter entrenched systems [13–17]. Different path dependencies can facilitate such lock-in [18], including cost advantages from specialisation of the incumbent system; a bias towards development of complementary rather than competing systems; reinforcement of institutional learning effects; and power asymmetry [15]. Kohler [19] notes that regimes exist not to innovate, but to bring about system optimisation and efficiencies. This system change via the niche is due to both the ability to exploit better-performing technology, and to offer society new types of behaviour and more sustainable consumption. To enable niches to affect such sustainable transition in a system, there must firstly be recognition, via social agency, that current systems cannot continue due to lack of sustainability, and a willingness to attempt a different practice [19]. Therefore, it may be argued that to remain competitive, the primary sector has followed established pathways and institutional arrangements that while supporting the main sectors to develop, also establish main-sector dominance at the expense of small niches.

To sustainably transition agricultural economies [20] farm systems need to restructure using innovation to mitigate against negative consequences such as emissions to air and water and animal welfare. Twomey and Gaziulusoy [21] state that for sustainability-based transformation, it is useful to think in terms of transitions rather than innovation shifts, as the elements of the transformation occur not at the individual production unit or process level, but throughout each [bioeconomic] sector. Silva and Stocka define transitions as "the need to shift from the current state of affairs to a re-arranged, renewed society in harmony with itself and its natural surroundings: a sustainable society" [22] (p. 60), while Bosman defines transition as "a fundamental change in the structure, culture and practices or a societal (sub) system that is a result of a co-evolution of economic, technological, institutional, cultural and ecological developments as different scale levels" [23] (p. 3). Transitions therefore aim to shift the system from its current norm through fundamental structural changes at different scales, to bring about an enhanced rearrangement that is more sustainable.

At a more general level, a number of research studies have been undertaken to quantify the ability to transition away from the current sustainable intensification regime using land use modelling (for example see [24,25]). Other studies have considered how to enable transformation through better understanding land-use decision making in order to facilitate adoption of niche production systems [26,27]. Such land use modelling is often either economically and/or environmentally based, concerned at the impacts and benefits from wholesale transition of land use from one sectoral system to another (for example see [28,29]). In contrast, land use decision-making is often studied at the scale of the individual farm system (due to the ease of studying a single farm unit and the land manager's reasons for wanting to transition), rather than as a larger regional or catchment level transition. There is a gap in being able to effectively quantify the impacts, benefits and unintended consequences from attempting to transform farming systems and land use into a more diversified mix of sectoral land uses, across a region.

Using the case of New Zealand, this conceptual paper explores how agriculture land-use could transition from conventional sustainable intensified agronomic use, towards alternative land-use systems. We hypothesize that transitioning New Zealand agriculture from a dominant sustainable intensification model, requires more diversified farming platforms at regional scale. In particular, this paper explores ways in which a transition away from the incumbent sustainable intensification farming model can be made that enables farm systems to become more integrated, co-operative and circular in nature. As part of this we highlight a range of alternative reconfigurations of business and land-use (not necessarily mutually exclusive) that have been considered either internationally or in New Zealand and assess them against a number of possible criteria. We also consider the processes and policy actions needed to support such transition. This includes the extent that market forces can pull us towards alternative systems or alternatively the extent that policy intervention will be required.

2. Methodology

2.1. Methods

Through a review of international literature relating to farm systems, we identified nine potential alternative land use configuration options that may allow land-use systems to become integrated into a cohesive agricultural whole operating at regional scale. Table 1 outlines aspects of the identified options. We discuss each in turn using an evaluative framework to assess the applicability to New Zealand, and impact on sustainability of farm systems at a regional scale.

Table 1. Definitions and Examples of Alternative Land Use Configurations.

Approach	Characteristics	Examples
Mixed farming	Mixed farming involves a system of farming which involves the growing of crops as well as the raising of livestock. According to the FAO, 'mixed farming is probably the most benign agricultural production system from an environmental perspective because it is, at least partially, a closed system. The waste products of one enterprise (crop residues), which would otherwise be loaded on to the natural resource base, are used by the other enterprise, which returns its own waste products (manure) back to the first enterprise. As it provides many opportunities for recycling and organic farming and for a varied, more attractive landscape, mixed farming is the favourite system of many agriculturalists and environmentalists.' [30], (p. 1 of Chapter 3).	Although numbers are reducing due to specialization, mixed farming systems are found in many regions of NZ. For example, a number of farms still have sheep and/or beef enterprises as well as crop enterprises [31]. However, there are challenges with viability across these systems.
Diversification	Diversification relates to farmers taking a portfolio approach, producing alternative species or products to protect against market downturn. Often, but by no means always, this takes the form of a small proportion of land being dedicated to niche production, while the main production continues under an intensified management regime.	An early diversification in livestock production was the farming of deer [32]. Another example of an industry niche sector expansion through diversification is the wine sector, now an established regime within New Zealand's primary industry.
Infrastructural sharing	Taking lessons from the growth of the 'sharing economy', farm equipment and infrastructure could be either jointly owned in a co-operative between farm units; or each farm unit could invest in only certain items, and rent or lease infrastructure and equipment from others as required. Farm units would then not require as much capital investment, particularly for items that only have seasonal or occasional use. As many investments in equipment and production require scale, this supports a more consolidated and intensive regional farming model. This is linked to land-use because individual farms could grow a greater range of more specialized crops.	Machinery rings, which are common in a number of countries are an example of such an approach [33]. In New Zealand, a 50/50 sharemilking arrangement between farmers and DairyNZ for stock and land management is in place. (See Sharemilker model)
Diversified Specialisation	Diverse specialization sees instead of joint ownership or lease of equipment, that farmers might become 'specialised land managers'- providing a service to a variety of land owners choosing to invest in certain land uses. In this way, the whole of a farm unit could still be intensively managed, but by a number of different farm managers who are contracted to provide the specialized management service. Land tracts become more diversified, but individual farmers do not need to become experts across multiple farm enterprises. Farmers may own similar size units, but only manage a portion of their own land, while also managing on contract portions of neighbouring properties that are being farmed in their specialist land use.	This model exists for production of root crops (such as carrots and potatoes) [34] where due to need for rotations and specialist equipment, growers often rent land across a number of farms to grow the crops. Flying flocks/herds exist where owners move their animals across a number of farms.
Intensified Diversification	Intensified diversification relates to 'producing more diversified products off the same parcel of land', preferably with minimal additional inputs into production. Examples usually include either finding markets for wastes or byproducts; or growing a diversified crop alongside the main production unit.	Some examples from New Zealand include: Baby doll sheep in Yealands vineyards. The sheep primarily keep the grass down between rows of grapes, but also provide another diversified farm product; Recreational and ecotourism services from forests; Deer co-products such as tails, pizzles and sinews [35].

Table 1. *Cont.*

Approach	Characteristics	Examples
Land Sparing	Land sparing refers to the concept of sparing land for biodiversity conservation and was introduced by [36] to characterize zoning policies that set aside land from agricultural production for maintaining local biodiversity. This idea is sometimes referred to as "the Borlaug hypothesis", after Norman Borlaug, father of the Green Revolution, who considered agricultural intensification good for the environment as it concentrated production on limited land [37]. Within a regional area, it would mean that some land would be retired from farming whilst intensification occurs on the remaining land.	Set-aside within the EU and also the Conservation Reserve Programme in the US are examples of this type of policy in the farmed landscape. QE2 covenants may be seen as an example of this in NZ.
Land Sharing	In contrast to land sparing, this approach promotes agricultural practices with lower ecosystem impacts and aims to increase within-field biodiversity (so-called wildlife-friendly farming). Organic and regenerative farming fit into this category biodiversity credit	Again, looking to the EU we can see that this approach has been widely adopted through environmental programmes aimed at reducing the intensity of input use for example [38].
Patchwork	Under this approach land becomes a patchwork quilt of a variety of uses, through the establishment of maximum land footprints for any one land use activity. The original rationale for promoting a patchwork scale approach was to mitigate losses that could emerge due to large tracts of one type of production being destroyed due, for example, to a natural disaster. However, it can also be seen as a way to encourage diversity more generally in the landscape. Policy measures would be required to restrict the size of individual land use blocks, which would also have the benefit of reducing the risk of disease outbreak or natural disaster to each industry.	Such anti-consolidation policies have been employed in the past in New Zealand to restrict individual farm unit size [39], but not on a land usage basis.
Industrial/Land- use Symbiosis	The underlying aim of industrial symbiosis is small scale circularity to reduce waste in production. In effect, the idea is that two or more industries are associated and co-located together, such that the wastes from one industry become the feedstocks for another's production unit. At the larger scale, industrial symbiosis engages separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or byproducts. Waste by-products from one industry are used by another in a co-dependent economic relationship for mutual benefit. Land can play an important part in this process.	The models have been used extensively in Europe (e.g., Kalundborg, Denmark) [40]. In a NZ example, the principle has been adopted between local wood processors, geothermal energy production, government, R&D, indigenous and logistics and service agencies in the Kawerau region. At the individual level, some forms of agriculture do practice a 'whole-systems' approach, typically biodynamic and organic ventures, often at a small scale, although increasingly sectors are adopting such practices.

2.2. Evaluative Framework

Our review outlines a number of configurations that have been discussed internationally or nationally. These include: lowering the intensity of current systems (known as land sharing); taking land out of agriculture altogether in intensively farmed landscapes (land sparing); getting more out of current systems (intensified diversification); encouraging more diversity in terms of agriculture (mixed farming) which can be supported by infrastructural sharing or diversified specialization; regulating land uses (patchwork approach) and; taking a regional planning approach (based for example on the concept of industrial symbiosis). The aim is not to be exhaustive, but illustrative of the sorts of changes that may occur which help to reduce intensity in our farmed landscape and/or integrate alternative less-specialized land-uses. Some tackle the diversity of land-use, but not necessarily its intensity (or vice versa) whilst others may address both dimensions.

A key factor is the likely impact on the sustainability of regional farming systems. In this sense, would such an approach on a regional scale enhance economic, environmental and social performance of land-use or are there inherent trade-offs. Another consideration is the extent that the land-use configuration improves the resilience of a region to shocks such as market downturns, disease outbreaks or climatic events. Other possible considerations relate to the ease and likelihood of the transition taking place. For example, in the adoption literature there is evidence that the greater the change required in the farming system the less likely adoption is to take place [41]. This links to a wider issue which is the complexity associated with the transition process. For example, the more actors required (i.e., farmers, processors, policy-makers etc.) to achieve the change, then the more complex the transition is likely to be and the more difficult to achieve. A further issue is the likely extent and nature of policy intervention required to achieve the transition. If the changes can be driven by the market (i.e., responding to profitability) then they may be easier to achieve and may require simple education/extension types of activities. However, any gains may be short lived if market forces change [42]. If extensive policy intervention, such as regulation is required, it may make it harder to get buy-in from land managers, but depending on the nature of the policies, any gains achieved may be more secure. Given that we are interested in land-use at the regional level, scaling is an important consideration. As noted by [27] scale is of major concern both to individual land owners, who want to be able to allocate reasonable areas of their farm to specific enterprises, as well as regions so that it can have a significant impact on land use as well as the economy.

3. Results and Discussion

It is clear from Table 1, that examples of many of these 'models' already exist internationally and also can be found in New Zealand—although generally on a small scale. This section briefly considers how they may be evaluated in terms of their applicability to New Zealand at a regional scale.

Whilst a lot is known about land-use in New Zealand, less has been studied about the systems that occupy this land. Historically New Zealand agriculture moved from pastoralism to pastoral farming [43], but has moved over the past 30 years towards more a model of sustainable intensification [44]. In New Zealand, some of the issues arising from sustainable intensification include: a largely unsustainable reliance on livestock production; reaching of our environmental limits in terms of nutrient flows, water quality, and soil nutrients; social license issues around water quality and animal welfare; unintended consequences from poor land use decisions; safety in production, and lost revenue from commodity production and export rather than value added and high value production [45–50]. Whilst there is a consensus from outside the sector, if not within, that a transition is required [13], what is much less clear is what a transitioned sector would look like in terms of land-use and how such a change can be achieved.

3.1. Classifying New Zealand Farm Systems

New Zealand agricultural systems have been classified in several ways by independent sectoral groups. For example, Dairy New Zealand classifies dairy farm systems into 5 types depending on reliance on imported feed; Beef + Lamb NZ classify 8 different agricultural farm classes for livestock production (see Table 2); the New Zealand Agricultural Production Census provides data on land use by main farm activity type (horticulture, sheep and beef, dairying, arable cropping, forestry) and there is a New Zealand soil classification system used extensively by agronomists. What is clear is that the proportion of agricultural land being used for different farm activities is fluid over time (Figure 1), with a major shift over the past decades towards particularly dairying and arable cropping, and away from sheep and beef and forestry (Table 3).

Table 2. New Zealand farm classifications for livestock farming, as outlined by Beef + Lamb NZ (Source: https://beeflambnz.com/data-tools/farm-classes, accessed on 15 January 2021).

Farm Type	CLASS	Animal Stocking	Number of Farm Units
South Island high country	Fine wool sheep, with wool as the main source of revenue.	Minimal	200
South Island hill country	Mainly mid-micron wool sheep (75%) and 25% cattle	2–7/ha	600
North Island hard hill country	Steep hill country or low fertility soils running mixed stock	6–10/ha	920
North Island hill country	<Class 3 soils. Stock sold in prime condition	7–13/ha	3055
North Island intensive finishing farms	Easy contour farmland with the potential for high production.	8–15/ha	1045
South Island finishing-breeding farms	This is the dominant farm class in the South Island, and includes irrigation	6–11/ha	1820
South Island intensive finishing farms	High producing grassland farms with some cash crop.	10–14/ha	1040
South Island mixed cropping and finishing farms	A high proportion derived from grain and small seed production as well as stock finishing.	minimal	465

Table 3. Agricultural production activity in New Zealand—proportions of total land use by sector.

	2002 *	2009 *	2017 **	% Change between 2002 and 2017
Horticulture	1.40%	1.50%	-	-
Sheep & Beef	69%	66%	45%	−24%
Arable	0.74%	2.40%	6%	5%
Dairy	12%	15%	21%	9%
Forestry	14%	12%	8%	−6%

Sources: * [51]; ** [52].

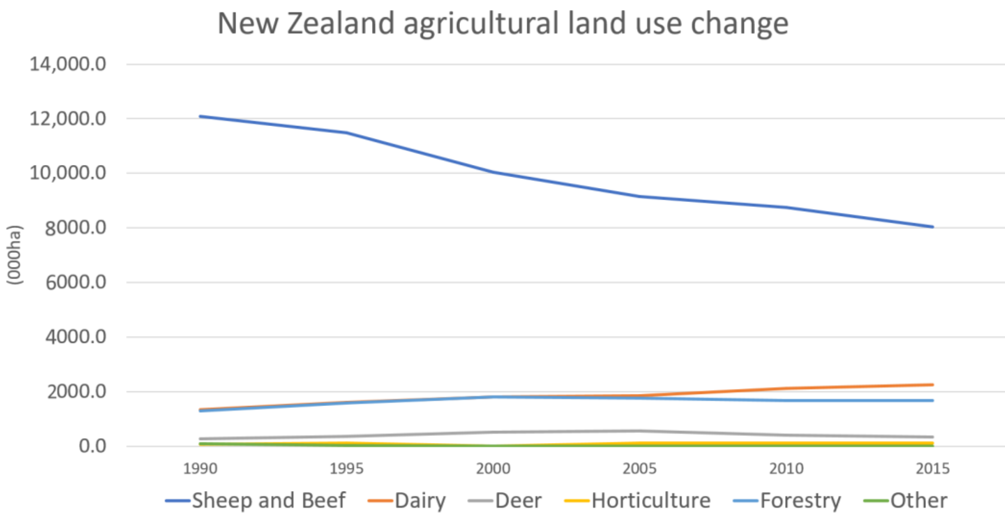

Figure 1. Changes in agricultural land use activity in New Zealand from 1990–2015. [51].

When considering alternative farming systems, Therond et al. [53] classify models of agriculture to the degree to which the biotechnical functioning of agriculture is based on ecosystem services versus external inputs and the degree to which their relationship with socio economic contexts are based on global market prices versus territorial embeddedness. Tables 2 and A1 in Appendix A, outline the characteristics of alternative systems across these dimensions as classified by Therond et al. [53]. Using this approach they identify six broad classifications of farm systems across these dimensions as highlighted in Figure 2. On the basis of these dimensions, it would seem reasonable to place the majority of New Zealand systems in the bottom left quadrant of Figure 1. That is, they operate generally in a globalized commodity-based food system and whilst intensity does vary between chemical and biological based inputs, in general they sit between the two.

If we accept that the current farming model is pushing against its constraints [45–50], the framework is also useful for considering in which direction New Zealand could go. In the context of the earlier classification of farming systems, it is useful to consider the extent that a change in direction will push regional systems into Qii, Qiii or even Qiv of Figure 2. It may seem that the 'ideal' system lies in the top right of Quadrant (iv) where alternative farming systems are embedded territorially. However, given the size of the sector in relation to the population size of New Zealand, it is clear that there will be a reliance on global markets to a significant extent. At the scale of agriculture we have now, New Zealand is too small in terms of population (at around 5 million) to support a truly territorially embedded agricultural sector within alternative local food systems (currently over 80 per cent of food production is exported, and over 60 per cent of forest harvest is exported [54]). Downscaling the majority of agriculture to the size required for Qiv would seem neither necessary nor desirable for our economy and the existing global markets reliant on our products. This said, there is scope for transitioning the types of farm systems that are operated and potentially systems of land-use could shift to be closer to those in Quadrant (iii) or to some extent Quadrant (ii) which would relieve some of the social and environmental pressures. While there are examples of Qii or Qiii systems operating in New Zealand, they are not widespread or operating at scale.

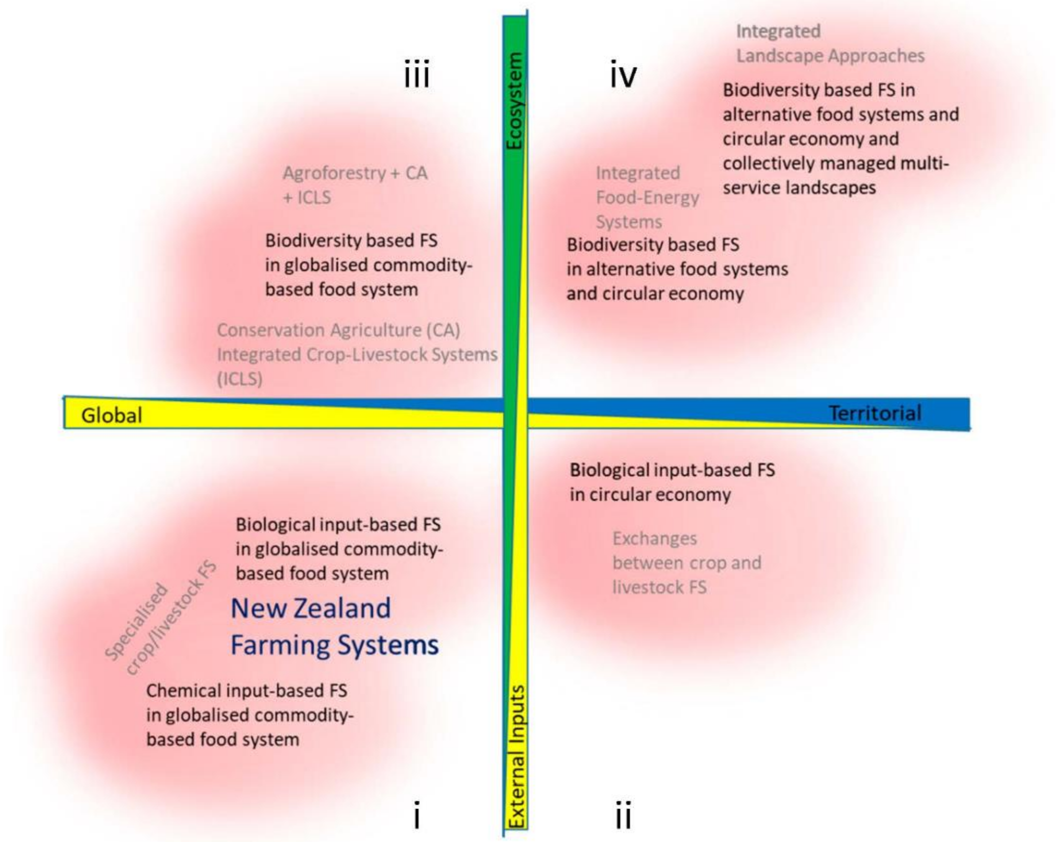

Figure 2. Possible Classification of Farming Systems. Source: Adapted from Therond et al. [53].

3.2. Evaluative Assessment of Alternate Land Use Models.

Table 4 presents an initial attempt at assessing the various models of land-use across these criteria. This evaluation shows that while some options can easily be scaled, other options require substantial effort to incentivise markets (market development), or regulation to assist a transition away from current predominant land-uses. New Zealand adopts a largely market-led approach to land-use, governed by sectoral economies, counter-balanced through regulations at local and national level [37]. Transitioning farm systems away from current land-use models requires mechanisms to ensure that should land managers wish to transition (due to disincentives or incentives), there is adequate market development to provide a benefit to transitioning towards a new niche. Doing this at a scale that will make a real difference to our current land-use configurations requires cross-agency collaboration and strategic policy development that provides a set of levers to both push (through disincentives) and pull (via markets and incentives) land management to adapt [13,55].

The following sections consider the processes and policy actions that may be needed to support such transition, within the broad classifications, with particular emphasis on providing examples of current policy disincentives and market development to support emerging niche farm systems within New Zealand.

Table 4. Brief Assessment of Models of Land-Use.

Approach	Main Impacts on Sustainability	Complexity	Resilience	Role of Market	Possible Policy Interventions	Degree of departure from Current System	Scalability
Land Sparing	Environmental Gain.	Medium at regional level as could require trading of production rights on land	Increase resilience by introducing buffer into landscape	Requirement for fallow areas could be part of supply contracts	Regulation to take land out of production. Could introduce trading. Possible financial incentives	Relatively small if simply retiring parts of farm. Stays in Qi	Can easily be applied at regional level
Land Sharing	Environmental Gain	Medium at regional level if trying to maximise environmental gain	Lower intensity may reduce disease pressures but may increase financial pressures	Premium for credence attributes could encourage change. Supply contracts could demand changes	Regulation of intensity. Incentives for extensification	Large if move to low intensity systems from high intensity ones. Can move to Qii/Qiii	Depends on viability of lower intensity systems
Intensified Diversification	Economic Gain	Low as relates to individual land owner. Niche development can add complexity to system	Economically more resilient but landscape may not change	Market will provide opportunities for alternative products	R&D to support development of new products	Relatively small as producing new products from similar system. Stays in Qi	Need for markets/supply chain infrastructure to achieve scale
Diversification	Environmental Gain	Low based on individual land owner. Niche development can add complexity	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be large and may move to Qii or Qiii	Need for markets supply chain infrastructure to achieve scale
Infrastructural sharing	Economic Gain	Medium requires co-ordination across land managers to achieve scale	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be large as will be new enterprise. May move to Qii or Qiii if integrating say livestock with crops	Sharing can help with scale issue but need for markets for products
Diversified Specialisation	Economic Gain	Medium requires co-ordination across land-managers to achieve scale	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be small if just involves making land available. However, may move to Qii or Qiii if integrating say livestock with crops	Need for markets supply chain infrastructure to achieve scale
Patchwork	Environmental Gain	Medium/High depending on specification (extensive and intensive margins)	Regionally area will be more diversified	Low driven by policy not markets	Regulation to enforce patchwork. Could introduce trading scheme	Potentially large at regional scale. May force farms to be more integrated (Qii or Qiii) or may end up like land sparing	High but may incur significant economic costs on farms in region
Industrial Symbiosis	Environmental and Economic Gain	High as likely to require co-ordination across land managers and possibly other industrial sectors and range of stakeholders	More circular/closed system will increase resilience	Cost savings and increased profitability could support change	Support industry development. R&D support	Large change due to re-thinking of systems. Possible move to Qiii or Qiv	Easier to achieve at smaller scale as larger scale with more players will become increasingly complex

3.3. Reducing Intensity by Land Sharing and Land Sparing

Internationally, Green et al. [56] initiated extensive debate on the advantages and disadvantages of land sharing (wildlife-friendly) farming in relation to a land sparing strategy, for conservation [12,57,58]. At a national level it is possible to identify New Zealand's approach to conservation and biodiversity as being one of land sparing. This contrasts sharply with the European Union, for example, where because of the interlinkage between farming and biodiversity, land sharing is a more common model. Although it should be noted that through policies such as set-aside, which has morphed into Ecological Focus Areas (EFA), land sparing is practiced within the EU. Similarly, systems that reduce emissions (on a per hectare basis) and increase biodiversity through reduced intensity within the farming system are not widely practiced (though there is increasing interest in such practices as regenerative agriculture and farm forestry). In contrast to New Zealand where regulation has been the main mechanism to control intensity (for example by introduction of farm environment and nutrient plans or nitrogen caps in specific areas), within the EU, land sparing has been undertaken through a carrot and stick approach; with the carrot being payments through CAP environmental schemes and the stick regulation (Although it also needs to be noted that by no means is the EU approach universally seen as successful in combatting the process of intensification).Whether or not New Zealand has the appetite for this dual form of intervention at scale is a key question. At regional council level, payments are made to land managers, for example to undertake practices that help regenerate land suffering from erosion. The challenge would be identifying where the funds would come from to support the scaling up of such schemes. It should be noted that whilst reductions in intensity internationally have largely been driven through government intervention, that is not the whole story. Private sector schemes have developed that address these issues in response to the concerns of consumers [59]. For example, Tesco, the UK supermarket chain, introduced Nature's Choice in 1991 which tied supply contracts to practices enhancing the environmental performance of the production system and Marks and Spencer launched Plan A in 2007 with the aim of making all their activities carbon neutral as well as helping their suppliers cut their emissions. Renwick and Wreford [42] note that the dominant role of supermarkets in the food supply chain is well recognized [60] and, therefore, they have the ability to exert significant pressure on their suppliers. In addition, premiums for foods with organic or other credence attributes has encouraged adoption of lower intensity systems. The ability of these to alter intensity at scale in New Zealand does depend on the extent that land managers can capture any potential premiums that emerge [61] or the extent that access to markets requires such practices. In the absence of strong market drivers, it is likely that government intervention will be required to achieve regional scale changes such as these.

Land sparing and land sharing approaches can operate at the individual level, but greater gains are likely to occur if they take place at catchment or regional scale. Examples of the sort of approach that could be adopted can be seen with the Central Plains Water scheme in the Canterbury Region [62], where the level of nitrate emissions are measured at the scale of the scheme and not individual land managers within the scheme. A further example is the innovative Lake Taupo nitrogen cap and trade scheme which established a catchment-wide cap on nitrogen losses by allocating farmers individual nitrogen discharge allowances and allowing those farmers flexibility to trade allowances amongst themselves [63]. This provides the opportunity to optimise production within the scheme through, for example, retiring less productive areas and farming productive areas more intensively.

3.4. Mixed Farming

Mixed farming systems are beneficial for the environment [64] while also enhancing the resilience of regional farming systems to such shocks as commodity price falls, climate change impacts and disease incursions [41]. Notwithstanding a general trend away from such systems in developed countries, mixed farming models continue in areas like the Canterbury Plains, despite the growth of intensive dairy systems in the region. However, these mixed farming systems whilst providing a desirable mosaic of land-uses and being more of a closed system, often struggle to remain viable, due to the relatively low returns from non-dairy livestock systems as well as traditional grain crops [27]. Therefore, the challenge here is not so much transitioning these mixed farming systems (although they are not without their own environmental challenges), but finding ways to enhance their overall economic returns so that they can be maintained.

Diversification of enterprises at the individual farm level, can support the development of mixed farming. Often these enterprises begin as niches but can grow. However, as noted by [27] there are a range of challenges to diversifying into niche products. First, they can be time consuming, deflecting attention from other aspects of the farm business. Second, often the farmer has to find markets for the products themselves, which requires a different skill set. Third, even if the niche becomes successful, it is hard for one individual to operate at a scale that can fulfil growing demand.

Diversified specialization or infrastructural sharing can potentially make diversification more viable by reducing costs or enabling access to more lucrative markets. This can support the mixed model of farming. They can improve viability by reducing the capital costs and/or allowing scale to be achieved to service international markets. In this manner, establishing a regional niche enterprise is de-risked in two ways. First, if enough farm units agree to diversify then this requires a small portion of their farm to be dedicated to the niche, but critical mass can still be reached. This is as opposed to a single farm unit needing to have critical mass and a larger proportion of dedicated land committed to the niche. Second, the farm manager has more confidence of success in the niche enterprise with expert management, so is more likely to diversify. Whilst it may support farms to develop alternative enterprises on their farms and hence support the mixed farm model, the overall impact on the three dimensions of sustainability will depend upon the nature of the enterprises. For example, the inclusion of trees in the landscape or an organic enterprise is likely to have different effects from the inclusion of another intensive arable crop or livestock enterprise.

An issue with diversified specialisation relates to the willingness of land-managers to allow others to make land management decisions on their property. Whilst based on a small sample, Renwick et al. [27] interviewed land managers who were supportive of the idea of specialised diversification. Some farmers who had specialty crops on their land (for example, high value seeds) noted that often the management regime was determined for them and did not see much difference between this and others growing crops on their land. Internationally, specialised potato or carrot growers already operate this way, due in part to the rotational requirements of these crops [34]. Infrastructural sharing, whilst still requiring co-operation, does not require cessation of rights over the land. However, agreement still needs to be reached over such issues as when individuals have access to machinery and the sharing or maintenance costs. Timeliness is a key success factor in agricultural production and therefore scheduling needs to be considered carefully. It is clear that with both infrastructural sharing and specialised diversification high levels of trust between those involved is required as well as strong contracts.

As with land sparing, one possible way to facilitate the process of co-ordination and collaboration is to bring together groups that may have formed for another purpose (for example around irrigation schemes or because of land use challenges (for example, the North Otago Sustainable Land Management Group, NOSLAM) [65]. One of the advantages of using existing groups is that trust is likely to have already been established across the group [16]. As well as horizontal co-ordination (across producers) there is a need to consider vertical co-ordination (between producers and processors for example) particularly in production of specialist products. Individuals or even groups of producers may not necessarily have the skills or resources to fulfil these roles. Organisations are emerging with the purpose of undertaking this horizontal and vertical co-ordination by, for example, identifying the needs of processors and pulling groups of farmers together to fulfil that need [66]. This provides mutual benefits for processors who get security of supply and for producers who get the security of a longer-term contract [67].

3.5. Patchwork and Land-Use Symbiosis

The patchwork approach influences land-use by stipulating maximum areas that may exist within regions or catchments. It could possibly also work by placing requirements for rotations onto farms. This latter idea has been introduced in the EU in intensive arable areas. The patchwork approach has a number of possible advantages similar to those of mixed farming (for example, increasing diversity and resilience). However, this presupposes that there are profitable alternative enterprises that can be farmed in the landscape. If this was not the case the outcome may be more akin to land sparing, intensive crops up to their maximum allowable area and then other areas effectively left fallow. Such a regulatory approach whilst offering a buffer in the landscape, does raise fundamental questions, including how the maximum areas are determined. Depending on how the regulation was enacted it may also potentially constrain land owners in terms of finding alternative uses that achieve the same objectives, but at lower cost for example. The patchwork approach generally operates at the extensive margin in terms of what land cover (e.g grass or crop) is allowed where, but not at the intensive margin (i.e., how much fertiliser or pesticides that are applied to crops or grass or how heavily the area is stocked). This said, aspects of intensity could be incorporated into a patchwork approach.

The most 'planned' of our land-uses lies within the concept of industrial symbiosis [68]. Industrial symbiosis aims for small scale circularity to reduce waste in production. In effect, two or more industries are associated and co-located together, such that the wastes from one industry become the feedstocks for another's production unit. Basically, multiple industries are using collaboration and industrial synergies to support a close-looped production system—though most are not completely close loop but the production cycle(s) are enhanced through the various industrial associations around supply. This may require planning at the regional level and needs strategic co-ordination. Whilst examples of these relationships may be seen at small scale (for example see [69]) it is more challenging to plan for them at a regional level. If they require co-locating other parts of the food or fibre supply chain (processing, manufacture, etc.) and potentially other industries as well, then again this will increase the complexity. Evidence of cost saving or revenue enhancement may be the key drivers for different types of enterprises to collaborate. These approaches have the advantage that they can engage a range of interested stakeholders in the process of designing landscapes that meet their needs but again this does increase the associated transaction costs.

3.6. The Role of Niches

For a mixed use landscape to emerge (or be maintained), a range of enterprises, either in their own right or combined, need to provide a sufficient income to meet the needs of the land-manager. However, as noted above, many farms are struggling to generate sufficient income from many of the current main enterprises, for example from traditional arable crops or sheep or beef. Therefore, either alternative uses for these traditional crops are needed (that generate higher returns) or alternative enterprises are required [70]. There are many such enterprises already in place in New Zealand, operating on a niche scale either within farming systems or on small-holdings (e.g., dairy sheep, tree nuts, truffles, alternative grains, etc.). A number of enterprises have successfully broken out of these niches, such as wine grape production, kiwifruit, deer, avocados, etc. [35]. However, a much larger number of enterprises, many of which have been around for a number of years, have failed to establish themselves at scale despite the apparent existence of market demand. An example is chestnuts where several attempts have been made to develop a regional chestnut sector in the Waikato, and there is a ready market, but it has failed to get off the ground each time as it required a local coolstore and critical mass of farm supply [71]. This reflects the fact that often there is the chicken and egg problem, firms will not invest in the infrastructure (e.g., processing capacity) unless supply is forthcoming, but producers will not produce unless the processing capacity is in place. To enable a larger proportion of land to be converted to diversified activities, not only greater economic returns from niche production are needed, but also there needs to be extensive market and supply chain development [72,73]. Extensive research and development within a fully functioning innovation system [74] is required to increase the number of viable alternative systems available to land managers. However, as noted by [35] a problem is that the current research system is set up to support the currently dominant sectors (dairy, sheep and beef, etc.) and not to support the development of niches. Linked to this is the fact that at 1.2 per cent of GDP, New Zealand's expenditure on R&D is only around half of that of the OECD average [75]. Therefore, there may be a role for government to support this development if there are potential market failures. This could particularly be the case for establishing low intensity niches or where there is a trade-off between value and intensity. It would seem less applicable for niches which are of high value and low intensity.

3.7. Markets and Policy as Drivers of Change

In New Zealand, the market has driven the development of the current models of farming with their inherent advantages and disadvantages. Or put another way, the land-uses that are found in New Zealand are the physical manifestation of the global demand of the final products from agriculture. The overall demand for land is a derived demand emanating from the demand for the products that it can produce. In a similar manner, the way the land is used is also derived from the nature of the demand of products. One argument may be that the market is unlikely to drive a transition away from such systems. This ignores the fact that there are market trends, which are driving demand for products with a range of credence attributes which can attract premiums [76] that are related to land-use decisions [77]. When discussing market drivers in New Zealand, it is important to consider the nature of these markets. The fact that the majority of food production in New Zealand is exported means that it is global markets that are driving demand [70]. More specifically, it is possible to identify a range of countries which are (or are likely to be) the main consumers of New Zealand products (Figure 3). Therefore, it is reasonable to argue that it is the nature of demand from consumers in these countries and not New Zealand itself which will determine the market influences on land-use. As many are middle-income (emerging) economies it may be argued that the major concerns are food safety and quantity rather than the credence attributes associated with food products. However, there is evidence of increasing concern around credence attributes in these countries driven through the emerging middle classes [77,78].

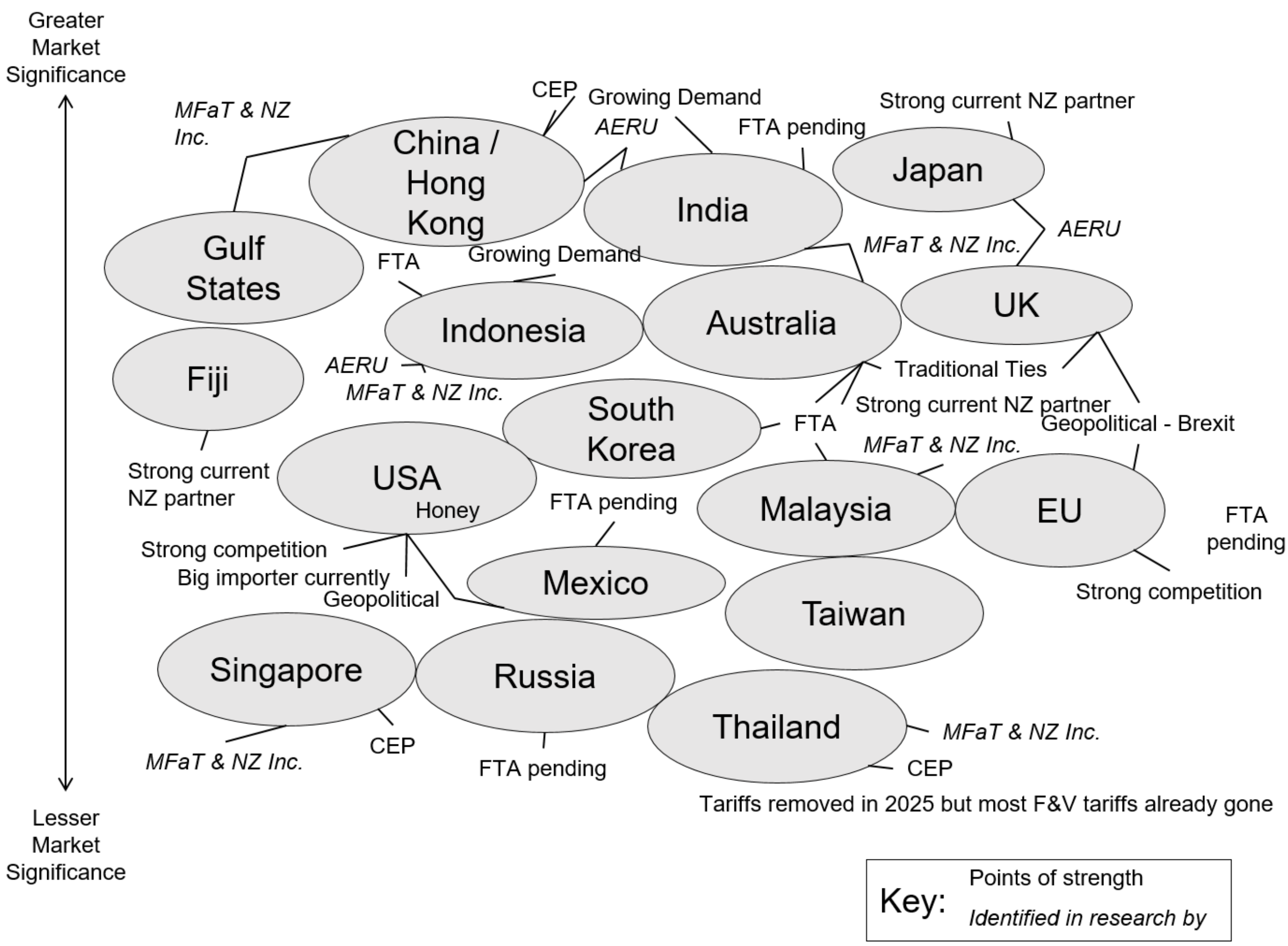

Figure 3. International Markets for New Zealand Products. (Adapted from [79]).

Pannell [80] notes a number of policy options that are available to achieve changes in management of privately owned land that could assist in driving land use transition. For example, he highlights that existing agri-environmental programmes from around the world use a range of mechanisms to encourage change, including education, awareness raising, technology transfer, research and development, regulation, subsidies, and other economic instruments [80]. He categorizes these mechanisms into five types defined as: positive incentives; negative incentives; extension; technology development and; no action, before providing a framework for assessing the most appropriate situations for use of the different policy options on a private-public continuum. The idea of how the net benefits are distributed between private and public across our various transitions could be a useful way to consider the nature of the policy intervention required. Looking internationally, lessons can be learned as to the effectiveness, efficiency and equity associated with these policies in terms of driving transitions in land-use [35,81,82]. Many of the policy actions are targeted at individual land-owners but this becomes harder when trying to achieve landscape or regional changes as this requires actions *across* land owners. Transitioning societal norms towards pro-environmental behaviours has similar limitations, and requires a longer term effort and critical mass in values [83].

Land-use decisions have been more responsive to short term market decisions whereas the challenges facing the sector today and the development of alternatives to help tackle these challenges requires a longer term vision and strategy. The problem is that current responses to environmental, economic and social pressures within the primary sector in New Zealand are based around incremental changes to the status quo, and significantly, within existing production systems or sectors: dairy, sheep and beef, forestry, with very little interaction between the sectors. There is a need to step back from focusing on any one sector or driver of change to investigate what dynamics support a transformation across the entire primary sector, and who can influence them. Sustainable agricultural transitions increasingly rely on integration and 'coupling' across niche supply chains, and between sectors to achieve greater circularity [84]. At another level, there is also the need to consider the potential scientific and other tools available that would be needed to assess land change impacts across a region or catchment (these could include land-use modelling (economic and spatial) in conjunction with Multi Criteria Decision-making (MCDM) and market and policy development). These tools could help support 'smarter' land use allocation for example by potentially assisting the continuation of some high value enterprises that are highly polluting or intense within the catchment if their impacts are offset by other strategically placed enterprises that mitigate these effects, bringing emission levels down for the region as a whole. The spatial-economic tools can also help to identify the best areas for each alternative land use arrangement within each region, taking into account the physical aspects of the land, the regional requirements for employment and existing infrastructure/enterprise and the joint visions for the catchment land owners [25,85]. This does involve a degree of intervention in land-use choices beyond that which has been witnessed so far. A challenge is that, in good faith, land managers may have invested many millions of dollars in transforming their properties, but that now (or in the near future) these locations may not be deemed suitable for that specific land-use. There then becomes a question of equity in the process. For example, forcing farms into bankruptcy through regulation may not be seen as a fair answer to the problem.

4. Conclusions

A combination of global (e.g., climate change) and local (e.g., water quality) drivers are pushing for a transition in our land-use systems in New Zealand. This paper has highlighted how a range of alternative configurations could help address these challenges at a regional scale. These range from land sharing and sparing, through mechanisms to support a more mixed landscape, to a regional planning approach. Analysis shows that each has potential advantages and disadvantages in terms of achieving the objectives of transitioning regional land use. The overall impact on the sustainability and resilience of New Zealand farming systems depends not so much on the general classification of systems, but more on the nature of the enterprises that emerge within the systems. Much work has been undertaken in New Zealand in relation to understanding the suitability of land for alternative uses, and in theory this could underpin regulations about the distribution of land-use. However, many enterprises may technically be suitable to be grown in certain areas, but if they are not viable they will not enter the system without some form of intervention. Whilst the focus of this study has been land use for New Zealand, it is clear that the issues discussed concerning the strengths and weaknesses of alternative configurations are relevant to many countries who are grappling with the challenges of transitioning agricultural land use, particularly to enhance Sustainable Development Goals for the environment and society. This said the context in New Zealand is different because countries like the US or regions like the EU already have significant public funds directed at agriculture that could be targeted at enabling a transition to more sustainable land uses. New Zealand's inherent agricultural system is known to be internationally competitive despite removal of farm subsidies, and policies to reduce agricultural subsidies in a similar manner to the New Zealand late 20th century agricultural policies are being touted as a model for other nations to follow [86]. Instead, there could be more useful policy lessons from incentivizing alternative land configurations, economic and actor collaborations (especially from less-productivist agricultural systems, for example within developing regions) that could enable faster transition while remaining competitive, and not lead to the sustainability issues New Zealand has created from intensifying post-subsidy land production.

The process of analysing the options highlight a number of common themes that will be critical to the transition process. A thread that runs through the paper is that many alternatives begin as niches and that to provide viable alternatives that can have an impact at a regional scale there is a need to grow niche enterprises into established ones. A mosaic that emerges from simply mixing intensive farming systems can still have some advantages in terms of improving the resilience of the sector, but one that incorporates higher value lower emission enterprises will provide greater overall benefits. Markets can be identified for a range of products in New Zealand's key trading partners, but it is quite a step from identifying a demand to fulfilling that demand in a way that returns value to land managers in New Zealand.

There is a role to play for government in facilitating the development of viable alternative land uses by for example investing in R&D (or providing incentives for the private sector to invest) and creating an environment in which innovation can thrive. Past New Zealand policy instruments around regulating farm size, farm output pricing and subsidies to enable continued economic viability for current farm systems have made way for more targeted policies that ensure land-based economic sectors are adequately protected in terms of resource (including employment skills, overseas investment and R&D capability). These have largely allowed sectors to freely and competitively respond to the market demand and to grow New Zealand's agricultural output, and the efficiency in supply of output. Such policies have facilitated the growth in farm sector regimes, but created new issues in sustainability and land usage that pose barriers to niche entry and farm transitioning to more flexible forms of land management.

An aim should be to de-risk the process of land-use change so as to facilitate the transition process. On the flipside of this, if high value/low intensity systems cannot be developed at scale, then further regulation may be needed to engender change. To date regulation has been the main tool used, but whilst it is important, other policy mechanisms that reward farmers for providing outcomes valued by society will aid the transition process. The simple use of regulation has the danger of pushing current systems to the edge of viability and engendering severe economic damage to the sector. A balance between positive and negative incentives (and in fact across the full range of policy options) and investment in market development and new technologies is required to encourage the transition. It therefore requires efforts at the public-private interface to transition our farming systems.

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Appendix A

Table A1. Farming systems biotechnical functioning of agriculture based on ecosystem services versus external inputs.

	Main Objectives	Features
Chemical input-based farming system	• Increase input efficiency and decrease pollutions • Often associated with "sustainable intensification"	• Specialised farms with standardised practices in simplified crop sequences (few crops or monoculture) based on external chemical inputs • Landscape features imposed by environmental regulations
Biological input-based farming system	• Decrease impacts on biodiversity and human health by replacing some or all chemical inputs with biological inputs	• Specialised farms with standardised practices in simplified crop sequences (few crops or monoculture) based on external biological inputs • Landscape features imposed by regulations • Possible integration with livestock
Biodiversity based farming system	• Development and management of biodiversity to increase ecosystem services and decrease external inputs • Often associated with "(agro)ecological intensification"	• Diversified farms with site dependent agro-ecological practices in diversified crop sequences • Non-crop habitats to increase ecosystem services (in compliance with regulations) • Possible deep integration with livestock in "integrated crop livestock systems"

Source: Therond et al. [53]

Table 2. Alternative systems based on global market prices versus territorial embeddedness.

	Main Objectives	Features
Globalised commodity based food system	• Increase productivity and efficiency via industrial processes and standardised techniques • Generic and standardised commodities without specific quality, leading to competition centred on globalised market prices • Concentration of power in large companies while farmers have an ever-decreasing share of the total added value and decisional autonomy • Negative impacts on the environment and human health	Regional or global levels
Circular economy	• Developed in opposition to linear and open globalised commodity-based food systems, to limit resource scarcity, waste and pollution and possibly improve economic performances • Based on the "3R" principles (reduce, reuse, recycle) and "symbiosis networks" of a variety of complementary agents to develop eco-efficient and closed loops of material and energy • Farming systems use organic matter (for soil fertility) or produce biomass (for bioenergy) • Provides farming systems with (i) alternative locally produced inputs (e.g., organic matter) and (ii) opportunities for diversification (e.g., biomass for energy production)	Local or regional levels

Table 2. *Cont.*

	Main Objectives	Features
Alternative food system	• Developed in opposition to globalised food systems to address issues of human health, environment conservation, animal welfare, taste and freshness, local producers and development • Specialised agricultural products produced with specific knowhow or in a specific "place" or targeted to specific consumers • Local product or local production to "re-spatialise food" • "Value-based supply chains" based on trust, collaboration, transparency and equitable relationships between all participants to "re-socialise food" • Food has multiple forms of value (beyond the price) • Provides farmers and local economies with opportunities to retain a larger portion of added value and supports diversified farming systems and landscape conservation	Local, regional or global levels
Integrated landscape approach	• Rural/territorial development projects that support and are supported by development of multifunctional landscapes to meet social expectations about ecosystem and socio-economic services • Integrated management of the nexus of Food/Non-food/Natural Resources to develop local/regional sustainable agriculture • Collective governance of multiple land managers to design the spatial distribution of land use (crop-grassland pattern) and seminatural habitats to increase the targeted ecosystem services provided to farmers, inhabitants and the global population • Provides farmers and local economies with opportunities to retain a larger portion of added value and supports diversified farming systems and landscape conservation	Local or regional levels (e.g., rural park level)

Source: Therond et al. [53].

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